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Peripheral MRA: Competing in the MDCT Era

Introduction

Peripheral arterial disease (PAD) is caused by the general systemic process of atherosclerosis manifesting in the lower limb distal to the aortic bifurcation and is a major problem in the population of those 55 years and older (1). The most frequent clinical manifestations of PAD include intermittent claudication and critical limb ischemia characterized by rest pain and/or tissue necrosis. The estimated incidence of critical limb ischemia in industrialized countries is 500–1000 new cases per million persons per year (2). If PAD is suspected based on patient history, the patients usually undergo a diagnostic two-step process. First non-invasive tests including physical examination, measurements of ankle-brachial indexes as well as Doppler examinations are performed to document the severity of the disease.

If PAD becomes lifestyle limiting or an interventional or surgical revascularization is considered the patients go on to the next diagnostic level, which typically involves obtaining an arteriogram. The precise definition the location and the extent of stenoses is a prerequisite for clinical decision making prior to surgery or percutaneous intervention (3,4). Historically, detailed examination of the peripheral arteries necessitated invasive catheter angiography and opacification of the vessels by iodinated contrast agents, with the inherent risks of arterial puncture, potential allergic and nephrotoxic effects of contrast media, and the hazards of ionizing radiation itself for patients and staff. Within the last decade magnetic resonance (MR) angiography and computed tomography (CT) angiography emerged as non-invasive alternatives. Both MR angiography and CT angiography have been shown to be sensitive and specific techniques for the evaluation of peripheral arteries (5–8).

Technique of peripheral MRA

As the field of view of MR systems is limited to about 50 cm, MRA of the run-off vessels requires multiple 3D data sets to cover the arterial system from the renal down to the pedal arteries. Bolus-chase techniques employing multi-station table

motion were introduced in 1998 and allow for the stepwise assessment of the pelvic and runoff arteries within a single examination (5).

For the standard peripheral MRA examination the patient is placed supine in the MR scanner with arms either above the head or crossed over the chest. Most MRA exams are currently performed on 1.5 T systems. Surface coils are mandatory to achieve a high signal- and contrast-to-noise ratio. Following a non-contrast enhanced scout scan multiple 3D data sets covering the arterial vessels from the renal down to the pedal arteries are collected after automatic injection of a double dose of contrast using a power injector. Typical acquisition parameters include: TR < 5ms, TR < 2ms, FA 20-30°, field of view about 500 mm in the coronal orientation and a matrix of 512. Based on this standard technique several technical developments have recently been introduced to improve image quality and diagnostic accuracy:

- Peripheral MRA requires substantial compromises with regard to spatial and temporal resolution, because the acquisition time is limited to avoid venous overlay in the most distal station. Parallel acquisition techniques (PAT) have recently been introduced and use the spatial distribution of the MR signal received by different receiver coils with various anatomic orientations to increase spatial or temporal resolution without greatly increasing scan time (9).
- Venous overlay in the distal stations of the peripheral MRA can be a mayor problem limiting the diagnostic accuracy. To overcome this limitation hybrid MR angiography combines a high resolution dual-phase three-dimensional gadolinium-enhanced MR angiography in lower calf and foot after injection of a first contrast bolus and a multi-station bolus-chase MR angiography in pelvis, thigh, and upper calf using a second contrast injection (10).
- In contrast to the hybrid MRA which applies a dual injection scan protocol venous compression aims lengthening the arterial phase time window to avoid venous overlay. Therefore, a thigh cuff is placed at the midfemoral level and inflated to a pressure of 50 mm Hg by using a nonferromagnetic pressure gauge immediately prior to the contrast enhanced MR angiography (11).
- However, all multi-station techniques result in independent FOVs the require post-processing and limit comprehensive assessment of the anatomic information. Furthermore, repositioning of the table between discrete stations reduces the scan time efficiency and gradient non-linearities at the edges of individual field-of-views (FOV) have to be taken into account. These limitations have recently been eliminated introducing continuously moving table data acquisition schemes providing seamless volume coverage and optimized scan time efficiency (12).
- Most MR angiographies are performed with extracellular contrast agents; however newer MR contrast media are being developed. Blood-pool contrast agents for MR imaging that binds strongly but reversibly to human serum albumin in the plasma have been introduced. Because of this albumin binding, these compounds exhibit a prolonged plasma elimination

half-life and increased relaxivity. Due to the prolonged T1 shortening of blood, MR angiographic resolution and anatomic coverage can be improved, since a longer imaging window is available after a single injection. This is a potential advantage over extracellular agents (13).

Technique of peripheral CTA

Since the introduction of spiral computed tomography into clinical practice in 1991, CT has gained wide acceptance as a non-invasive technique for vascular imaging. In the pre spiral CT era computed tomography only provided limited coverage and poor spatial resolution. Currently, computed tomography angiography (CTA) exams are performed with multislice spiral CT scanners which collect up to 64 slices per rotation of the x-ray tube. Additionally, rotation times were dramatically reduced and computed tomography developed from a device that required several seconds to create a single slice to one in which multiple slices can be obtained in less than 500 ms. As in 3D contrast enhanced MRA, large volumes can now be covered in less than 60 seconds with high spatial resolution. The resultant data can be processed into thin axial images, as well as into maximum intensity projections or multiplanar images.

Good CTA requires contrast agent to be present in the vessels of interest throughout the time that the CT data sets are acquired. This is accomplished by starting the data acquisition when adequate contrast levels are present and by ensuring sustained contrast throughout the scan. This can either be achieved using the test bolus technique or an automated bolus-tracking system begins scanning when the density or intensity of an area defined by the operator exceeds a prescribed threshold.

Comparison of MRA and CTA

The introduction of multislice CT scanners improved reliability and accuracy of CT angiography and the technique is gaining increasing importance. However, due to rapid technical development of MRA and CTA it is as yet difficult to determine exactly what role both techniques will play for the assessment of peripheral vascular disease. MRA has obvious advantages over CTA with respect to radiation dose and contrast nephrotoxicity, which is especially important in the increasing number of patients with co-existing diabetes or renal disease. On the other hand, CTA may become an alternative to MRA in patients with pacemakers or defibrillators precluding the use of MRI.

Both techniques MRA and CTA require post-processing of the raw data, to obtain an arteriogram comparable to catheter angiography. The direct visualization of vascular calcifications achievable with CTA may have therapeutic relevance, but calcifications and osseous structures adjacent to the vessels impair the visualization of the vascular lumen. Therefore, MRA holds the advantage of faster and simpler post processing.

Although much research is needed to establish clinical guidelines for CTA and MRA only few prospective trials comparing the two modalities are available.

Willmann et al (14) compared contrast enhanced MRA and CTA using a 4-slice CT scanner of the aortoiliac and renal arteries in 46 consecutive patients, using intraarterial catheter angiography as the standard of reference. The study demonstrated no statistically significant difference between 3D MR angiography and multi-detector row CT angiography in the detection of hemodynamically significant stenoses. However, the time required to reconstruct and interpret CTA images was significantly longer than for MRA.

In a recent study, Ouwendijk (15) et al compared CTA performed on a 16 - detector row scanner with MRA. 157 Patients referred to evaluate the feasibility of a revascularization procedure were randomly assigned to undergo either MR angiography or CT angiography. The study evaluated the primary outcome and total diagnostic costs. There were no statistically significant differences in outcomes between the groups but diagnostic costs were significantly lower in the CT group compared with the MR group.

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